NEGATIVE INFLUENCES ON SHIELDING EFFECTIVENESS

Miroslav Hromádka

ABSTRACT

This article describes how can be shielding effectiveness (SE) measured and calculated. There are mentioned systems for SE measuring and possibility of their usage in our laboratory. Then there are introduced some factors influencing shielding such as holes and gaps in cover or cavity resonance.

KEYWORDS

Shielding effectiveness, electromagnetic compatibility, cavity resonance, waveguide

1. INTRODUCTION

Electromagnetic compatibility is ability of any device, equipment or system to work properly in area where sources of strange electromagnetic signals are and at the same time it doesn't interfere with the system environment.

Shielding is one of the most important instruments, how to ensure electromagnetic compatibility. Shielding protects the sensitive equipment against radiation of electromagnetic disturbance from source and provides its unproblematic function. In this context is shielding any enclosure that lowers electromagnetic field and it can be installed around source of electromagnetic emissions (could be one part of an equipment) or around equipment we want to protect. Sometimes it can be both, like the braids on coaxial cables. But effective shielding could be expensive, so it is usually the last tool we should use after solving optimal design and construction of electric device or system.

2. SHIELDING EFFECTIVENESS (SE)

We need to know electric (magnetic) field inside and outside of the enclosure to calculate shielding effectiveness. When we put these two intensities in proportion we get shielding coefficient [1, 2]:

$$K_S = \frac{E_T}{E_i} \text{ or } K_S = \frac{H_T}{H_i} \tag{1}$$

Where index T is intensity inside the enclosure and index i is intensity of the field on the same spot without the enclosure.

Shielding effectiveness is defined in decibels. It depends on frequency of the field and it can be calculated from the shielding coefficient [1, 2]:

$$SE(f) = 20 \cdot \log \frac{1}{K_S} = 20 \cdot \log \frac{E_i}{E_T} \tag{2}$$

In a case where E and H cannot be considered separately is SE defined in terms of power flow [1, 2]:

$$SE(f) = 10 \cdot \log \frac{P_i}{P_T} \tag{3}$$

In every case above the source is in one fixed position and the various parameters (E_i, E_T, H_i, H_T, P_i, P_T,) refer to values measurable at another fixed location.

Most of the practical shields aren't limited by the conductivity, permeability or thickness of the material but by defects (joints, technological or ventilation apertures, etc.) in the overall construction. Therefore I focused on these events in my measuring.

3. MEASURING OF SHIELDING EFFECTIVENESS

3.1. Measuring with ETS-Lindgren antenna set

Common available system for measuring of SE is antenna test set from ETS-Lindgren company.

Figure 1 - ETS-Lindgren antenna test set [3]

This set was designed for simply checking of the performance of a shielded enclosure. The set is first calibrated without any shielding. Included spacers maintain correct distance between receiver and transmitter. Then are the antennas placed on opposite sides of the enclosure. Spacers now maintain correct distance between antennas and shield barrier. Then we can find out the SE in decibels right on the LCD panel of the receiver antenna.

This set has a big advantage in quickness of calibrating, measuring and processing of results. Results are displayed right on LCD panel and they can be stored also and processed later on computer. Antennas are easy portable, so they aren't only for laboratory usage and they can be applied greatly in industry conditions.

But this system has also series of disadvantages. Shielding effectiveness is a function of frequency, but this set can measure only on 8 given frequencies (10 kHz, 156 kHz, 1 MHz, 8 MHz, 10 MHz, 16 MHz, 32 MHz, 64 MHz). That isn't enough for finding all properties of the shield. It can be used for primary raw measuring by the design of a device. Antennas are quite big (about 40 cm high and 30 cm wide), so they can be use only in cases of big enclosures, switchboards, boxes and shielding of whole rooms or buildings.

3.2. Measuring with immunity test system

System for testing electromagnetic immunity generates electric field of a constant value, such that we know the value of E_i from (1). It allows tune frequencies from 80 MHz to 3 GHz with a step of 1 %. This frequency step corresponds with requirement from ČSN EN 61000-5-7 standard. Electric field probe HI-6005 from ETS-Lindgren company is ideal for measuring inside enclosure with this system. This probe can measure electric field strength from 0.5 to 800 V/m and its frequency response is from 100 kHz to 6 GHz. Probe is only 8 cm high and 7.5 cm wide and so it is suitable for measuring even in small enclosures.

Figure 2 - Electric field strength probe HI-6005

Disadvantage of this system is its complexity and area requirements. We can use it only in laboratory conditions in anechoic chamber. Calibrating and measuring takes quite a long time and results aren't immediately available. SE has to be calculated from stored data in mathematical software. We made a model of enclosure with exchangeable front panels for experimental measurements. There is a typical characteristic of electric field strength inside the model with full copper panel on figure 3:

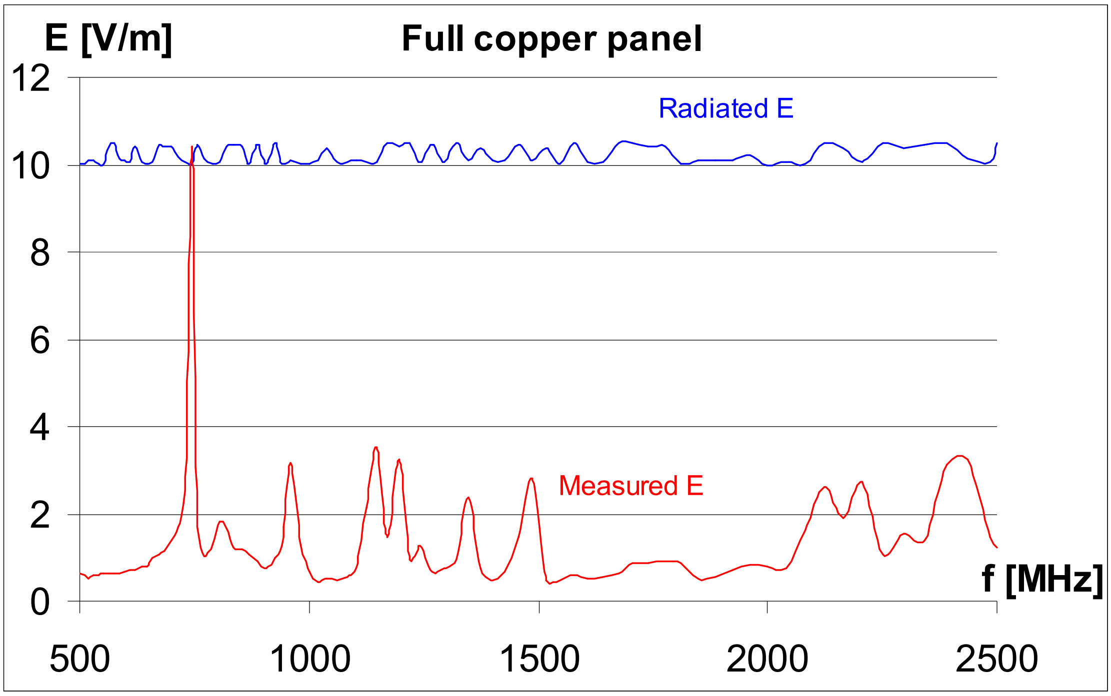

Figure 3 - Characteristics of E_i (blue) and E_T (red) on experimental model

4. NEGATIVE INFLUENCES ON SHIELDING EFFECTIVENESS

4.1. Apertures

The enclosure has to fulfil other technical requirements besides the shielding, which are necessary for proper function of an equipment such as cooling and ventilating, access to inputs and outputs or measuring points, repair ability, dismantling etc. So every enclosure has series of inhomogeneities, joints and apertures, which lower the shielding effectiveness. Apertures in enclosure are small slot antennas with a gain *G*. For a circular aperture of radius *a* is gain [1]:

$$G = \left(\frac{2\pi a}{\lambda} \right)^2 \tag{4}$$

Gain can be also expressed as:

$$G = \frac{P_T}{P_i} \tag{5}$$

Then the shielding effectiveness is:

$$SE = 20 \cdot \log \frac{\lambda}{2\pi a} \tag{6}$$

G is proportional to area, so we can write for *n* apertures:

$$SE = 20 \cdot \log \frac{\lambda}{2\pi a \sqrt{n}} \tag{7}$$

Real shields have finite thickness *t*, therefore is necessary to calculate the extra attenuation:

$$SE = 20 \cdot \log \frac{\lambda}{2\pi a \sqrt{n}} + \frac{32t}{2a} \tag{8}$$

For a slot aperture of length *l* is shielding effectiveness:

$$SE = 20 \cdot \log \frac{\lambda}{2l} \tag{9}$$

And with the extra attenuation:

$$SE = 20 \cdot \log \frac{\lambda}{2l} + \frac{27.2\, t}{l} \tag{10}$$

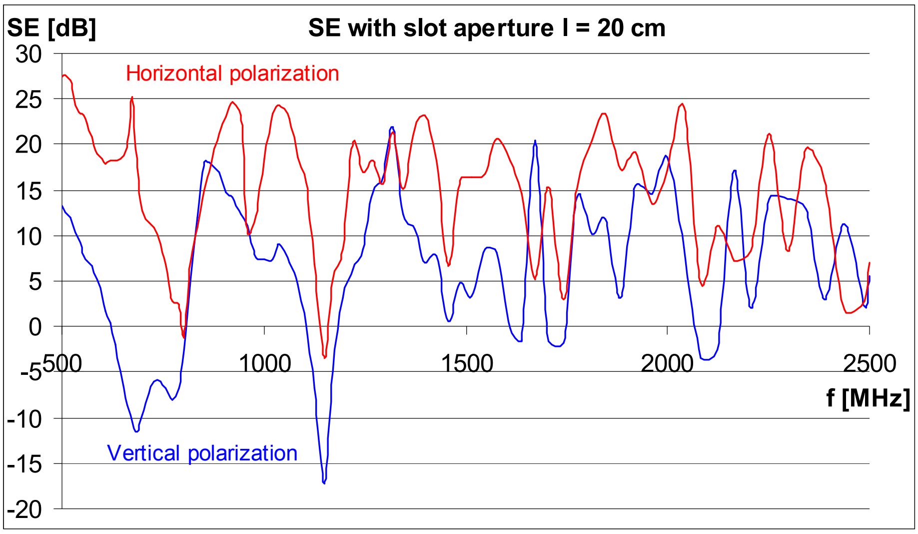

Figure 4 - SE of experimental model with slot aperture with different polarizations of antenna

4.2. Cavity resonance

Enclosures of any shape made from conducting material can act as cavity resonators. Metal walls allow reflecting of electromagnetic waves back and forth within the enclosure. This happens even if the structure has holes in it. Resonant frequencies for rectangular cavity are [1]:

$$f_{rez} = \frac{1}{2\sqrt{\mu\varepsilon}} \cdot \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{c}\right)^2} \qquad (11)$$

Where *a*, *b*, *c* are inside dimensions of the enclosure and *m*, *n*, *p* are positive integers.

Table 1 - Resonant frequencies for experimental model

m	**N**	**p**	**f_{rez} [GHz]**
0	1	1	0,84794112
1	0	1	0,74422412
1	1	0	0,74422412
1	1	1	0,95570477
0	1	2	1,34071263
1	0	2	1,27764461
1	1	2	1,41133902
0	2	2	1,69588224
2	0	2	1,48844824
2	2	0	1,48844824
2	2	1	1,60467450

There is simplified equation for the lowest resonant frequency in [4]:

$$f_{rez\ low} = 1.5 \cdot 10^8 \cdot \sqrt{\frac{1}{a^2} + \frac{1}{b^2}} \qquad (12)$$

Where *a, b* are two biggest inside dimensions of the enclosure.

5. CONCLUSIONS

The most limiting factors for shielding effectivenes are apertures, joints and other inhomogeneities. If you can’t avoid them, you can try to reduce their influence. Joints, doors, windows and access panels should have overlap if possible or you can fill up the free space with special shielding materials. If you can’t cover up the apertures, for example because of the cooling and ventilating, you can make them from bigger amount of smaller holes or append small grid behind them. Or you can increase the thickness of the material to create the waveguide with cut off frequency [1]:

$$f_c = \frac{1}{2\sqrt{\mu\varepsilon}} \cdot \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \qquad (13)$$

Then SE below this frequency is for narrow slot of length *a* and depth *z* where ($z \phi a$):

$$SE \approx \frac{27.2\,z}{a} \qquad (14)$$

And for circular waveguide of radius *r* is SE:

$$SE \approx \frac{15.991\,z}{r} \qquad (15)$$

Other negative factor for SE is cavity resonance. You can never avoid the resonance, but you can change magnitude of the enclosure to set the resonance frequency in harmless range for the shielded equipment.

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Authors:

Ing. Miroslav Hromádka
University of West Bohemia
Department of Electrical Power Engineering and Ecology
Univerzitní 8, 306 14 Plzeň, Czech Republic
E-mail: mhromadk@kee.zcu.cz